

PREVENTION OF CANINE RABIES IN RURAL MEXICO: AN EPIDEMIOLOGIC STUDY OF VACCINATION CAMPAIGNS

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Abstract. We compared three vaccination strategies in three rural communities in Mexico to determine the factors associated with the success of vaccination programs in areas where canine rabies is poorly controlled. In town A, intensive publicity and community participation were used; owners were instructed to bring their dogs to temporary centralized clinics for vaccination. In town B, only brief precampaign publicity was used, followed by vaccination at a centralized site. Minimal publicity was also used in town C, but the vaccination campaign was conducted house to house. A total of 5,426 residents and 1,597 dogs were counted in the three towns (mean human:dog ratio 3.4:1). In Town A, 70.1% (472 of 673) of the dogs were vaccinated; the campaign required 40 person-minutes per dog. Significantly greater proportions were vaccinated in town B (262 of 318 [82.4%]; $P < 0.001$) and town C (483 of 561 [86.1%]; $P < 0.00001$); each of these latter campaigns required 10 person-minutes per dog. The following factors were positively associated (by multivariate analyses) with vaccination of individual dogs: non-intensive publicity, house-to-house vaccination, dogs owned by a single member of the household, and dogs acquired > 15 days after birth. Intensive publicity did not increase the overall success of the vaccination program; the efficiency of centralized versus and house-to-house vaccination was comparable.

In the first half of the twentieth century, programs using the mass application of canine vaccines, leash laws, and the elimination of stray dogs were successful in controlling canine rabies in many developed countries, and completely eliminating it in others.¹⁻⁶ However, in most developing countries of Asia, Africa, and Latin America, canine rabies control and elimination programs have not been successful, and their cost and that of human postexposure treatment programs continue to consume scarce public health resources.⁷ In the 1980s, the continuing social and economic burden of the disease led both the World Health Organization and the Pan American Health Organization to initiate a number of programs aimed at the control of canine rabies.⁸⁻¹¹ In some countries, particularly in the Americas, mass dog vaccination programs resulted in control of enzootic dog rabies in many

urban areas.^{9, 12, 13} Limited hypothetical cost-benefit and cost-effectiveness studies suggest that mass canine rabies control and elimination programs are economically advisable in at least some developing countries.^{14, 15} However, in spite of these studies, rabies control programs have not been effective in many of these countries.

Several reasons have been suggested to explain the difficulty in conducting effective canine rabies control and elimination programs. Before vaccination programs can be initiated in new areas, some authorities believe it is necessary to study the biology of owned and stray canines and their relationship to human culture.^{11, 13} Surveillance must be initiated, preferably before vaccination, so that the successes can be documented and deficiencies corrected. Financial and human resources must then be obtained and a program administered. In some cases, the re-

TABLE I
Cases of human rabies, by the size of the patient's home town, in Puebla, Mexico, 1979-1988

Population of town (range)	Cases/100,000	% of total	Rate
1-499	6	6.8	0.18
500-2,499	34	38.6	0.26
2,500-4,999	23	26.1	0.33
5,000-9,999	17	19.3	0.51
> 10,000	8	9.1	0.05

sources (fiscal or human) necessary for rabies control may be excessive compared with those required for other public health priorities.¹⁵ These difficulties are reflected in resources used in several model rabies-control programs, which have required substantial international economic support and years of coordinated effort, and have proved extremely labor-intensive.^{10, 13} Such problems are compounded in rural areas, where inaccessibility and the lack of local veterinary public health services further increase the costs of vaccine delivery. As a result, some experts believe that oral canine vaccination may be the only feasible approach to mass canine vaccination in some areas.¹⁶

Adding to the difficulty in the design and execution of canine rabies control and elimination programs may be the lack of epidemiologic studies of factors associated with the success (or failure) of vaccination campaign strategies. For example, in centralized vaccination campaigns, one of the two principal strategies used to vaccinate dogs, dog owners bring their dogs to a few vaccination clinics located at key points around the city. Use of this strategy appears to have led to the control of rabies in several large cities in Latin America.^{9, 12} However, in some Latin American cities, centralized vaccination campaigns have failed and the other strategy, house-to-house vaccination campaigns (in which dogs are vaccinated at their owners' residences) must be used.¹³ Another aspect of mass canine vaccination campaigns that has not been subjected to scientific study is the role of intensive publicity, education, and local involvement in the community in which a particular campaign is to be conducted.¹³ Since the actual administration of vaccine takes only a minute or so per dog, the time required to elicit sufficient community participation, bring a sufficient proportion of the dogs to the vaccinators, and restrain these dogs so that they can be vaccinated must be critically studied; demands on the time of community leaders and members (who

certainly have many other priorities) must be made with caution.

We therefore decided to conduct a controlled study of vaccination strategies that would compare the acceptability of centralized and house-to-house vaccination campaigns; we also estimated the amount of time required to conduct all aspects of these programs. Using the data collected during the vaccination campaign, we attempted to determine the epidemiologic factors associated with the success of parenteral vaccination, and whether there were large numbers of dogs (stray or owned) that could not be vaccinated. Finally, we compared parenteral and placebo oral vaccination in owned dogs to determine which method would reach a larger proportion of the canine population.

METHODS

Background

A review of 1989 national rabies surveillance data for Mexico (Secretaria de Salud, Subsecretaria de Servicios de Salud, Direccion General de Medicina Preventiva, Programa de Control de la Rabia: Problematica y Avances, 1989, unpublished data) revealed that rates for human rabies were higher in the state of Puebla (0.2 per 100,000) than in the country as a whole (0.08 per 100,000), and that rates for towns with populations under 10,000 were up to ten times higher than rates in urban areas (Table 1). Within Puebla, the small rural towns surrounding the municipality of Atlixco (population 60,000) were particularly affected. In these small towns, the rates of canine rabies and postexposure treatments were higher than in other communities of similar size in this state. We identified three similar small towns near Atlixco (designated towns A, B, and C). Canine rabies had been reported in each of these towns, but a vaccination campaign had not been conducted in the previous year.

Precampaign publicity and vaccination campaign strategies

In each town, we provided public education regarding rabies, took a complete canine and human census, and conducted a town-wide dog vaccination campaign. Three different strategies were used (Table 2).

Town A. A centralized vaccination campaign

TABLE 2
Summary of strategies used in this study

Intervention	Town A	Town B	Town C
Week 1			
Publicity and community participation	Intensive	Normal	Normal
Census and dog ecology studies	Yes	No	No
Week 2			
Vaccination	Central-point	Central-point	House-to-house
Census and dog ecology studies (Monday-Wednesday)	No	Yes	Yes

was preceded by an intensive house-to-house educational program during the five-day period before the vaccination campaign. In this program, teams went from house to house distributing educational information on rabies and encouraging household residents to participate in the forthcoming rabies vaccination campaign. Each team was composed of three persons, including a member of the community or a health worker known to the community and a member of the campaign team trained in rabies education. At the same time, a questionnaire was administered. Information about the vaccination program was also disseminated through public announcements over mobile systems, public posters, radio, and announcements in schools two days before the campaign.

Town B. An intensive educational program was not conducted. All precampaign publicity was disseminated two days before the campaign, using media identical to those used in town A. Residents of town B were told to bring their dogs to one of three vaccination clinics near their houses.

Town C. As in town B, there was no intensive educational program. Through a two-day publicity program similar to that used in towns A and B, the residents of town C were informed that vaccinators would come to their houses.

Data collection

Information about each dog and its household was obtained during a house-to-house survey by using a standardized questionnaire, either before (town A) or after (towns B and C) the vaccination day. In town A, the survey was conducted so as to attempt to stimulate maximum interest about the vaccination campaign and to educate the inhabitants about rabies and its prevention. In towns B and C, an identical survey was conducted during the three days after the vaccination

campaign, so that it would not affect owners' decisions to have their dogs vaccinated during the campaign. Data collected about the dogs included their names, age at the time of survey and at acquisition, their principal use, and the owner's identity. Household data collected included information on the size and age distribution of the family, type of floor, wall, and roof of the house, an assessment of the respondent's knowledge of rabies, and information about the number and circumstances surrounding dog bites sustained in the last year by persons living in the household. Dog bites were classified as a rabies risk if the attacking dog was proven rabid, died, or disappeared within 10 days of the bite.

Vaccination and marking of dogs

On the Sunday after the initiation of the house-to-house education and survey in town A, and the brief publicity campaigns in all three communities, vaccination campaigns were conducted in each town. In two of the three towns, each vaccinated dog was marked with a brightly colored collar to allow the subsequent estimation of the canine population. One day later, we walked (or drove slowly) through the town, counting the number of dogs with and without collars in the street and on private property. We then estimated the actual canine population using a Lincoln Index.¹⁷

Vaccine coverage and efficiency

To determine what factors besides campaign strategy accounted for the differences in vaccination rates, we considered a number of characteristics of the dogs or of the household. For dog characteristics (age, sex, principle use of the dog, position of the owner in family), each dog was considered separately. For household characteristics (number of humans and human:dog

ratio in the household, construction materials), we compared the proportion of dogs vaccinated in each household.

To determine the relative efficiency of each of the three strategies, we calculated the amount of time (person hours) necessary to vaccinate the dogs in each of the three towns. We included the time required to educate the public, including the house-to-house educational program and survey in town A, the two-day community-wide publicity program in all three towns, and the time required for the actual vaccination campaigns in all three towns.

Comparison of acceptance of parenteral and placebo oral vaccines

We used data from the parenteral vaccination campaign in town A to compare the acceptance of parenteral vaccine to that of a placebo oral vaccine.¹⁸ We determined which of the 245 dogs randomly selected to receive the placebo oral vaccine had been vaccinated in the parenteral vaccination campaign and compared this with the proportion that accepted the placebo oral vaccine.

Statistical analysis

Nonparametric univariate (chi-square test, Wilcoxon rank sum test, and Spearman rank correlation test) and multivariate (logistic regression) analyses were used to compare the proportion of dogs vaccinated in the three towns and to determine the characteristics of individual dogs that might have been associated with the owner's decision to have the dog vaccinated during the one-day campaign. To compare characteristics of the households or dog owners that may have been associated with household compliance or noncompliance with vaccination, we determined the vaccination rate (number of dogs vaccinated divided by total number of dogs in household) in each house. Because the rates clustered heavily around 0% or 100%, the households were divided into two groups: those that vaccinated less than 50% of the dogs and those that vaccinated 50% or more. We then compared the vaccination rates according to selected household characteristics, using univariate (chi-square, Wilcoxon rank sum test, Pearson's correlation coefficient) and multivariate (logistic regression) statistical analyses.

RESULTS

Household survey and human and canine census

A total of 865 houses were included in the survey of the three towns; 42 (4.9%) of these appeared to be unoccupied. Excluding these, interviews were completed in 764 (92.8%) of the 823 occupied households (Table 3). The main reason for failure to conduct interviews was that occupants could not be located despite two additional visits to 52 households. The occupants refused to be interviewed in only two households.

The canine and human censuses in the three towns indicated that 5,426 people and 1,597 dogs were living in 764 households; the number of dogs per household showed a correlation with the number of humans ($R = 0.26$, $P = 0.0001$). There was a median of seven humans and two dogs per household. The mean human:dog ratio was 3.4:1 and the median ratio was 4.5:1. In all three towns, most of the houses were made of adobe and had dirt floors.

In the year preceding the survey, 30 residents (2.4 per 1,000) of the three towns reported being bitten by dogs. The age-specific rate of dog bites was highest in individuals over the age of 65 and in those between the ages of 5 and 14 (Table 4). Of these, 13 were found to have a sufficient risk of rabies to require rabies postexposure prophylaxis. The rate of bites with rabies risk was highest in persons over 65 years old.

Although the three towns were in general quite similar, there were some differences among them (Table 3). Town A had more dogs per household and more dogs for each human (i.e., a lower human:dog ratio) than towns B or C; the latter two towns did not differ significantly from each other for these features. Houses in town A were more likely to be made of cheaper construction materials (adobe or straw) than those in town B, and those in town B were more likely to be made of these materials than those in town C. Similarly, houses in town A were more likely to have dirt floors than those in towns B or C. The number of persons per household did not differ significantly among the three towns.

Results of canine vaccination campaign

Epidemiologic information was obtained on 1,552 (97.2%) of the 1,597 dogs identified in the census (Table 5). Overall, 78.4% of these dogs

TABLE 3
*Characteristics of households, human population, and canine population, by town**

Characteristic	Town A	Town B	Town C	Total	Differences between towns†		
					A versus B	B versus C	A versus C
Total houses	292	251	322	865			
Households interviewed	260 (89.0)	203 (80.8)	301 (93.4)	764 (88.3)			
Households owning dog(s)	201 (77.3)	140 (69.0)	225 (74.8)	566 (74.1)	NS	NS	NS
Floor type							
Dirt	185 (77.1)	125 (69.4)	170 (58.5)	480 (67.7)	NS	NS	19.8 (<0.0001)
Cement, tile, or wood	55 (22.9)	55 (30.6)	119 (41.2)	229 (32.3)			
Construction material							
Adobe or straw	203 (84.2)	109 (74.7)	155 (53.8)	467 (69.2)	NS	17.66 (0.0001)	55.48 (<0.0001)
Brick, block, or cement	38 (15.8)	37 (25.3)	133 (46.2)	208 (30.8)			
Rabies prevention knowledge							
Accurate	174 (69.1)	126 (78.3)	220 (75.9)	520 (74.0)	NS	NS	NS
Inaccurate	78 (30.9)	35 (21.7)	70 (24.1)	183 (26.0)			
Total humans	1,824	1,365	2,237	5,426			
Humans per household	7	6	7	7	NS	NS	NS
Total canine population	710	319	568	1,597			
Median per household	2	1	1	2	26.4 (0.0001)	NS	13.2 (0.0003)
Human : dog ratio							
Median	3.0	6.0	5.0	4.5	18.9 (0.0001)	NS	15.4 (0.0001)
Mean	2.6	4.3	4.0	3.4			
Age at study (months), median	3.0	3.0	4.0	3.0	NS	NS	NS
Age at acquisition (months), median	1.0	1.0	1.0	1.0	NS	NS	NS

* Households for which information was missing or unknown are excluded from individual analyses. Values, unless otherwise stated, are the no. of households (%).

† Chi-square (P) values are shown if differences are statistically significant. NS = not significant.

were vaccinated during the one-day campaign (Table 5). The proportion of dogs in town A that were vaccinated (70.1%) was significantly lower than that in towns B (82.4%; $P < 0.001$) or C (86.1%; $P < 0.00001$); the proportion of dogs vaccinated in towns B and C did not differ significantly. In most of the households, either all or none of the dogs were vaccinated. All dogs were vaccinated in 404 (71.4%) households; none of the dogs were vaccinated in 86 (15.2%) households. Even if the analysis is limited to households with two or more dogs, all or none of the dogs were vaccinated in 80.6% of households.

TABLE 4
Number and rate of dog bites in towns A, B, and C, 1989

	Age group (years)					Total
	0-4	5-14	15-44	45-64	> 65	
All bites	1	13	11	1	4	30
Rate*	1.1	7.7	5.9	1.5	17.7	5.7
Rabies risk†	1	8	2	0	2	13
Rate*	1.1	4.7	1.0	0	11.3	2.4

* Bites/1,000 population.

† Biting dog was found to be rabid, or escaped, died, or was killed without observation.

TABLE 5
Proportion of dogs vaccinated, by selected characteristics of individual dogs*

Group or characteristic	Town A	Town B	Town C	All towns	Differences between towns†			Multi-variate analysis
					A versus B	B versus C	A versus C	
All dogs	472/673 (70.1)	262/318 (82.4)	483/561 (86.1)	1,217/1,552 (78.4)	16.9 (≤ 0.001)	NS	44.6 (≤ 0.00001)	NS
Age at study								
< 3 months	219/282 (77.7)	103/123 (83.7)	169/200 (84.5)	491/605 (81.2)	NS	7.7 (0.006)	3.6 (0.06)	
≥ 3 months	253/391 (64.7)	159/195 (81.5)	314/361 (87.0)	726/947 (76.7)	17.7 (≤ 0.0001)	NS	50.2 (≤ 0.00001)	
Within town (P)	< 0.001	NS	NS	0.036				
Age at acquisition								
< 15 days	338/491 (68.8)	133/160 (83.1)	257/321 (80.1)	728/972 (74.9)	12.3 (≤ 0.0001)	NS	12.5 (0.0004)	≤ 0.001
≥ 15 days	134/182 (73.6)	129/158 (81.7)	226/240 (94.2)	489/580 (84.3)	NS	15.5 (≤ 0.00001)	34.8 (≤ 0.00001)	
Within town (P)	NS	NS	< 0.001	< 0.001				
Sex								
Male	227/324 (70.1)	177/208 (85.1)	291/333 (87.4)	695/865 (80.4)	15.7 (≤ 0.0001)	NS	29.6 (≤ 0.0001)	NS
Female	206/298 (69.1)	78/102 (76.5)	191/227 (84.1)	475/627 (75.8)	2.0 (0.16)	NS	15.8 (≤ 0.00001)	
Within town (P)	NS	NS	NS	0.03				
Use of dog								
Companion/mascot	29/59 (49.2)	20/21 (95.2)	45/50 (90.0)	94/130 (72.3)	13.9 (≤ 0.001)	NS	20.7 (≤ 0.00001)	
Work/guard	401/549 (73.0)	241/296 (81.4)	434/507 (85.6)	1,076/1,352 (79.6)	7.4 (0.007)	NS	25.1 (≤ 0.00001)	NS
Within town (P)	< 0.001	NS	NS	NS				
Owner of dog								
Household	144/229 (62.9)	41/63 (65.1)	195/244 (79.9)	380/536 (70.9)	NS	NS	16.9 (≤ 0.0001)	< 0.0001
One person	289/393 (73.5)	218/252 (86.5)	288/317 (90.9)	795/962 (82.6)	15.4 (≤ 0.001)	NS	34.6 (≤ 0.00001)	
Within town (P)	0.005	< 0.001	< 0.001	< 0.001				

* Dogs for whom information was missing or unknown are excluded from both the numerator and denominator. Values are the no. of dogs vaccinated/no. in each group (%).

† Chi-square (P) values are shown if differences between towns are statistically significant. NS = not significant.

TABLE 6
Vaccination proportion according to selected household characteristics*

Characteristic	Town A	Town B	Town C	Total	Differences between towns†			Multi-variate analysis
					A versus B	A versus C	B versus C	
All households	145/201 (72.1)	116/140 (82.9)	199/225 (88.4)	460/566 (81.3)	NS	18.12 (0.00002)	NS	8.98 (0.0027)
Rabies prevention knowledge								
Accurate	110/144 (76.4)	74/90 (82.2)	157/175 (89.7)	341/409 (83.4)	NS	10.3 (0.0013)	2.98 (0.08)	NS
Inaccurate	33/47 (70.2)	22/30 (73.3)	41/47 (87.2)	96/124 (77.4)	NS	NS	NS	NS
Construction material								
Brick, block, or cement	21/26 (80.8)	27/31 (87.1)	89/102 (87.3)	137/159 (86.2)	NS	8.18 (0.0042)	NS	NS
Adobe or straw	113/152 (74.3)	54/69 (78.3)	103/114 (90.4)	270/335 (80.6)	NS	10.94 (0.00094)	NS	
Floor type								
Cement, tile, or wood	34/41 (82.9)	29/35 (82.9)	74/83 (89.2)	137/159 (86.2)	NS	NS	NS	
Dirt	103/140 (73.6)	64/81 (79.0)	118/133 (88.7)	285/354 (80.5)	NS	NS	NS	NS
Humans/household, median								
Low proportion‡	7.0	5.5	8.0	7.0	NS	NS	NS	NS
High proportion	7.0	7.0	7.0	7.0	NS	NS	NS	
Human : dog ratio, median								
Low proportion	2.0	2.4	4.1	2.5	NS	NS	NS	NS
High proportion	2.4	3.8	3.5	3.0	NS	NS	NS	
Dogs per household								
Low proportion	3.0	2.0	2.0	3.0	NS	NS	NS	
High proportion	3.0	2.0	2.0	2.0				

* Households for which information was missing or unknown are excluded from both the numerator and denominator. Values, unless otherwise stated, are the no. of households with a high proportion of vaccination/total no. of households (%).

† Chi-square (*P*) values are shown if differences are statistically significant. NS = not significant.

‡ Low proportion = households with <50% of the dogs vaccinated; high proportion = households with ≥50% of the dogs vaccinated.

We therefore divided the households into two categories: low vaccination proportion (< 50% of the dogs vaccinated) and high vaccination proportion (> 50% of the dogs vaccinated). Using these categories, households in town A were less likely to have a high proportion of vaccinated dogs than those in towns B or C (Table 6).

The following variables were not significantly related to a high proportion of vaccinated dogs in the households: respondent's knowledge about rabies (knowing that the best way to prevent rabies was through vaccination), the quality of the construction of the house (adobe versus better building materials) or the type of floor (dirt versus finished floors), the human:dog ratio, the total number of dogs per household, and the total number of humans per household.

Dogs owned by a single member of the family (rather than communally) were more likely to be

vaccinated, as were those acquired > 15 days after birth (Table 5). The higher vaccination rate in dogs owned by a single member of the family compared with those owned communally reached statistical significance in all three towns, but dogs acquired > 15 days after birth were more likely to be vaccinated only in town C. The dogs used for work were more likely to be vaccinated than companion dogs in town A, but not in towns B and C. Vaccination was shown by multivariate analyses to be significantly associated with non-intensive publicity, ownership by one member of the household, and acquisition > 15 days after the birth of the dog.

Efficiency of the three strategies

The person-minutes per dog necessary to complete the vaccination campaign were lowest in

TABLE 7
Efficiency of vaccination campaigns by town

	Town A	Town B	Town C	Total
Dogs vaccinated	472	262	483	1,237
Total person-hours	330	43	83	456
Person-minutes per dog	40	10	10	22

towns B and C (10 minutes per dog) and highest in town A (40 minutes per dog) (Table 7). If the time used to conduct the intensive education campaign in town A is excluded from these results, the amount of time necessary to vaccinate each dog was similar in each town.

Estimation of the stray dog population

A Lincoln Index based on the proportion of dogs with collars was used as an estimate of the proportion of the actual dog population that was vaccinated in town B. Using this ratio and the total number of dogs in town B known to have been vaccinated during the campaign, we estimated the true canine population in town B to be 344 dogs (Table 8). The vaccination coverage in this town may therefore have been somewhat lower (76.2%) than that based only on census data. The canine population can also be estimated by correcting the census data for occupied houses where interviews were not conducted; using this correction, the canine population was 368. However, the vaccination coverage is not likely to have been as low as 71.1% (262 of 368); some of these uncounted dogs were vaccinated during the vaccination campaign in town B, but were not included in the analysis because their household could not be located or because no information was obtained during the census.

TABLE 8
*Estimation of the total canine population, using a Lincoln Index, in town B**

Collar	Property		Total
	Private	Public	
Present	38 (76)	23 (77)	61 (76)
Absent	12 (24)	7 (23)	19 (24)
Total	50 (63)	30 (37)	80 (100)

* Values are the no. (%). If the number of dogs with collars was proportional to the total number vaccinated, the total canine population is estimated to be 344 ($262 \times [80/61]$).

TABLE 9
*Comparison of parenteral and placebo oral vaccination in town A**

Oral bait consumed	Successful parenteral vaccination		
	Yes	No	Total
Yes	115 (52)	34 (15)	149 (67)
No	43 (19)	32 (14)	74 (33)
Total	157 (71)	66 (29)	223 (100)

* Values are the no. (%).

Comparison of acceptance of parenteral and placebo oral vaccines

In town A, we compared the acceptance of parenteral vaccine to the acceptance of an experimental bait containing placebo oral vaccine and a commercial dog biscuit. Of the 245 dogs randomly selected to receive the placebo vaccine, 22 were excluded from the analysis because of insufficient or incomplete information regarding the placebo oral or parenteral vaccination. Of the remaining 223 dogs, 157 (70.4%) had been vaccinated in the parenteral vaccination campaign and 149 (66.8%) accepted either the experimental bait or the dog biscuit (Table 9). Forty-three (58.1%) of the 74 dogs that did not accept either the experimental bait or dog biscuit had been vaccinated in the parenteral vaccination campaign.

DISCUSSION

In our comparison of different strategies for canine vaccination in rural Mexico, vaccine coverage and program efficiency were approximately equivalent in towns B and C, where either centralized site or house-to-house administration were used with limited publicity and community involvement. These strategies were more successful than the intensive education and centralized site vaccination campaign used in town A. Although the differences between the proportions of dogs vaccinated in the three towns were relatively small, these differences were of sufficient magnitude to influence the overall success or failure of a campaign. The proportion of dogs vaccinated in town A (70.1% of dogs counted in the census), for example, may or may not have been sufficient to interrupt transmission, while the proportions vaccinated in the other two towns exceeded the 70% coverage believed to be nec-

essary to interrupt the transmission of rabies in a community.¹⁹

One unexpected finding in this study was the large number of dogs in relation to the human population in these three rural towns. The overall human:dog ratios exceed those in rural parts of Sri Lanka and the Philippines, and in urban parts of Ecuador.^{11, 13, 20} Vaccination of such large canine populations will probably require human and financial resources in excess of those estimated for urban areas. These difficulties may be offset somewhat by the accessibility of the canine population in the three rural communities where our studies were conducted, where few, if any, stray dogs were found. The absence of a large stray dog population has also been documented in other developing countries.²¹

Also surprising was the lack of difference in the efficiency (person minutes to vaccinate one dog) of a centralized vaccination campaign (town B) and house-to-house vaccination (town C). Interviews with vaccination teams in towns B and C suggested that vaccinators in town C worked steadily throughout the entire day, whereas those in town B had completed most of their vaccinations during the morning. However, because residents of town B had been told that vaccination would be available at the three announced locations in the town until 4:00 PM, these workers remained at their posts until the end of the day, thus decreasing relative efficiency. This finding points out an important difference between centralized and house-to-house campaigns, in which the number of persons staffing vaccination clinics can easily exceed (or underestimate) the number required. In contrast, teams using the house-to-house strategy have more flexibility, including the possibility of returning to houses where no one was home or proceeding to other towns. Another possibility is to combine both approaches, with some personnel initially being assigned to centralized locations in a town, and later conducting house-to-house vaccination.

Even for the two most efficient campaigns, personnel requirements were considerable (10 person-minutes per vaccinated dog).¹² These estimates are probably not excessive. In an urban mass vaccination campaign in Lima, Peru, 250 people worked for 30 days to vaccinate 327,000 dogs and cats (10.8 person-minutes per vaccinated animal).¹² Substantial human resources are necessary for both urban and rural mass canine

vaccination campaigns. Although these programs may be cost-effective in comparison with the costs of modern human postexposure treatment,¹⁴ their tremendous resource requirements may make them quite expensive and therefore not cost-effective compared with other public health priorities.

The reasons why intensive publicity failed to favorably influence the proportion of dogs vaccinated in town A is unknown. It is possible that intrinsic differences between town A and towns B and C influenced our results. For example, a number of characteristics of households and dogs in town A suggested that overall, this town was somewhat poorer than the others. However, stratification of the data by a number of variables, including surrogates for household income, failed to identify any of the household variables that were associated with the success of vaccination in the three towns; town A still had lower vaccination rates than those in towns B and C.

Apart from campaign strategy, a number of factors appeared related to the success of canine vaccination in these three towns. In all three towns, dogs owned by an individual member of the house were more likely to be vaccinated than those owned commonly by the household. Dogs owned by a single member of the family may be more likely to be vaccinated because a particular person took responsibility for the dog's care, or because dogs owned communally were less controlled and therefore less likely to be vaccinated. A number of other factors were associated with success of the campaign in one town, but not the others. In town A, working dogs were less likely to be vaccinated than companion dogs, and dogs less than three months of age were more likely to be vaccinated than older dogs. In town C, where a house-to-house strategy was used, dogs born in the owner's home or acquired during the first 15 days of life were less likely to be vaccinated than those acquired later in life; this relationship was maintained among dogs greater than three months of age at the time of vaccination, as well as in those less than three months of age. Although the reason for this difference is not known, it is possible that dogs born in the home are frequently unwanted, and thus are less likely to be cared for.

The difference in vaccination frequencies among these three communities and the different

factors associated with vaccination and non-vaccination highlight the difficulty in performing fully controlled studies of canine vaccination strategies. In spite of every attempt to identify three similar towns for these studies, there were subtle differences between the towns that may have affected the response to the vaccination campaign. Town C was wealthier than town A, and the cooperation and support of the community leader in town C seemed somewhat greater. Nonetheless, although some of these factors may have contributed to the differences in the vaccination rates between the towns, no characteristic other than the campaign strategy accounted for most of the differences. To fully compare the effects of intensive versus normal publicity and a house-to-house vaccination strategy versus one based on a centralized clinic strategy, it would have been necessary to conduct the campaigns in four separate towns.

Oral rabies vaccination has been advocated as the only way to vaccinate most stray and community dogs and some owned dogs (such as those that cannot be restrained). Oral vaccination may also be more efficient with owned dogs in communities such as the ones in which we conducted our studies, since trained vaccinators and dog restraint personnel may not be necessary. However, a safe and effective oral vaccine has not yet been developed, and our studies suggest that there were relatively few dogs that could not be vaccinated with parenteral vaccines in these communities.

The responses to the three campaign strategies in these towns differed sufficiently (independent of the socioeconomic and demographic differences of the three towns) to allow several conclusions to be drawn. First, house-to-house and centralized location vaccination strategies appear to be equally efficient in terms of the proportion of the canine population reached and use of time. Centralized campaigns allow the dog owners the opportunity to have their dogs vaccinated at a convenient time during the day; this may be particularly important for owners (or dogs) not at home during the entire day. In contrast, house-to-house vaccination campaigns may be preferable if the campaign can be conducted at a time when dogs (and at least one human member of the household) are at (or near) home, since a high vaccination coverage is almost assured, residents of the community are spared the difficulty and inconvenience of bringing their dogs

to centralized clinics, and the proportion of the owned canine population vaccinated can be easily calculated by obtaining population information as the vaccinators proceed from house to house. Second, the intensive publicity and community involvement used in town A did not appear to motivate (and may have dissuaded) community participation in the vaccination program. It appears that intensive promotion should be limited to situations in which community acceptance in a vaccination campaign is unlikely or where conventional approaches have already failed. Finally, mass canine vaccination in towns such as these will require considerable human resources, and this factor should be carefully assessed before the campaign is begun.

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